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Lecture for M.Sc. IV semester students

M.Sc. IV sem

Paper - II, Unit - IV (Nuclear & Particle Physics)

Introduction → **Elementary Particles**

The elementary particles are to day undoubtly the focus of interest and of research for the experimental as well as the theoretical physicists. Experimental investigations of elementary particles all involve some source of particle to study and some way of detecting those particles and measuring their behaviour, but in case of practical investigation found that many elementary particles are unstable. The investigation of electromagnetic phenomena suggested that the atom had an internal structure. At that time the typical photo-type of all the elementary particle was the electron. The problem of the dualistic nature of matter was resolved by the quantum theory of fields: the elementary particles are nothing but the quanta of a corresponding field.

In 1932, when chadwick identified the neutron and Heisenberg suggested that atomic nuclei consisted of neutrons and protons, it seemed as if p, n and e^- were sufficient to account for the structure of matter.

Besides these there was the photon, the intermediary or field particle for electromagnetic forces, such as exist between the nucleus and electrons in the atom. If anti-matter exists it would then be made up of anti-electrons, i.e. positrons, anti-protons and anti-neutrons. Thus we see that seven particles could explain both matter and anti-matter.

In 1935, Yukawa postulated the existence of another particle, with a mass $m \simeq 200\, m_e$ as the field particle for the strong nuclear forces. Recently the extensive studies made partly on high energy cosmic ray particles and even more, with the help of high energy accelerators have revealed the existence of numerous new nuclear particles. Apart from a dozen or so the particles have very short lifetimes, very much less than 10^{-6} sec. They cannot therefore be regarded as normal constituents of matter. They are characterised by the parameters, mass spin, electric charge and magnetic moment. They have been decribed by such adjective as fundamental, strange and elementary, but none of these is quite appropriate.

The word fundamental implies that the particles are the basics building blocks of matter, but unstability of most of the particle indicates that the great majority are certainly not. It is true that their behaviour was strange in the early 1950, but it is much less now.

Classification of Elementary Particles →

The elementary particles are separated into two general groups, called bosons and fermions. These two groups have different types of spin and their behaviour is controlled respectively by a different kind of statistic i.e. Bose statistics & Fermi statistics.

Bosons are particles with intrinsic angular momentum equal to an integral multiple of $\hbar$. Fermions are all those particles in which the spin is half integral.

The most important difference between the two classes of particles is that there is no conservation law controlling the total number of bosons in the Universe, whereas, the total number of fermions is strictly conserved.

Boson → Boson is a term, which not only includes material particles but also includes those quanta and photons which arises form interactions. Thus in the case of the ~~of~~ simple electromagnetic field the bosons are the light photons or the X-Ray photons. The photon has a mass of zero and a spin of unity and is consequently described as a massless bosons. A massless boson, called a graviton with a probable spin of two units has been postulated as a field particle of gravity. These bosons created by the electromagnetic field are essentially of one kind, while the bosons formed in the strong interaction are of two distinct kinds. First there are those which are known as pions or π-mesons (π^+, π^- and π^0). The second group of bosons are much heavier than that of pions and are known as kaons or K-mesons (K^+, K^-, and $\bar{K}_0$)

Fermions → The fermions fall in two main classes, according to whether, they are lighter than meson or heavier. Those in the lighter group are often called leptons, whilst those in the heavier group are called baryons. The leptons are the electrons muons. and neutrions and their anti-particles. These are all with masses less than the pions and with spin half. Leptons interact weakly with other particles. Leptons interact weakly with other particles. The total number of leptons minus the total number of anti-leptons remains unchanged in all reactions and decay processes involving leptons and antileptons.

The baryons consist of the two nucleons with their anti particles (n^0, $\bar{n}^0$, p^+, p^-) and the hyperons. There is no reasons to doubt the existence of the anti-particles of these fermions. The total number of baryons minus the total number of anti-baryons is absolutley Conserved in all interactions.

The kaons and pions together with the baryons are placed into a group of strongly interacting particles called hadrons.

Classifcation of Elementary Particles